Opening Review: MHD waves in the solar atmosphere

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Abstract

The solar atmosphere supports a number of wave phenomena, as attested especially by the recent upsurge in SOHO and TRACE observations of waves and oscillations in the corona. Such observations provide considerable impetus to theoretical developments. The magnetically structured nature of the solar atmosphere, extending from isolated concentrations of field in the photosphere to magnetic loops in the corona, has led to the development of simple models of magnetohydrodynamic wave propagation in magnetic flux tubes. Here we give an overview of some of the basic features of such models, illustrating these concepts for photospheric conditions, for coronal loops, and for prominences. The new tool of *coronal seismology* is also discussed.

Session 1: MHD waves and Oscillations in Photospheric Structures

Invited Review:

P. Cally
(Australia)

Abstract

Invited Review: Correlated Intensity Oscillations in the upper Chromosphere and upper Transition Region above Active Region Plage

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Abstract

Although there are now many observations showing the presence of oscillations in the corona, their direct relationship to waves or oscillations in the photosphere and chromosphere is not well understood. We provide an overview of recent studies describing correlations between oscillations in the lower and upper atmosphere. We focus in particular on our recent wavelet analysis of observations (made with TRACE, the Transition Region and Coronal Explorer) of strong ($\sim 10-20\%$) intensity oscillations in the upper TR footpoints of hot coronal loops. They show a range of periods from 200 to 600 seconds, typically persisting for 4 to 7 cycles. These oscillations are not associated with sunspots, as they usually occur at the periphery of plage regions. A preliminary comparison to photospheric vertical velocities (using the Michelson Doppler Imager onboard SOHO) reveals that some upper TR oscillations show a correlation with p-modes in the photosphere. In addition, a majority of the upper TR oscillations are directly associated with upper chromospheric oscillations observed in Hα, i.e., periodic flows in spicular structures. The presence of such strong oscillations at low heights (of order 3,000 km) provides an ideal opportunity to study the propagation of oscillations from photosphere and chromosphere into the TR and corona. It can also help us understand the magnetic connectivity in the chromosphere and TR, and shed light on the source of chromospheric mass flows such as spicules.

Oral Contributions

Solar Oscillations in the Presence of Non-parallel Sub-photospheric Steady Flows and Atmospheric Magnetic Fields

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Abstract

Solar atmospheric (e.g. coronal) seismology is a rapidly emerging field. The present paper deals with the atmospheric effects combined with sub-surface (i.e. sub-photospheric) flow on the solar eigenoscillations (p and f-modes). In particular, non-zero angles between the magnetic field and the flow direction are considered. The dispersion relation is derived and solved analytically in the long-wavelength limit. Cases with higher values of the wavenumber are solved numerically. The relative importance of the solar atmospheric magnetic field and the flow in contributing to the frequency shifts is revealed in different wavelength ranges. In some cases these effects may cancel each other, so that the frequency shifts suffered by the p and f modes are minimal. In other cases the two effects act in unison yielding a maximum increase or decrease in the frequency. Observational implications of these theoretical results in the context of low-atmospheric seismology are discussed.

Active Region oscillations as observed by CDS, EIT and TRACE

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(2) IAC, Tenerife, Spain

Abstract

We will report observational evidence of high frequency active region oscillations in active regions. We will follow one active region from one limb to the disk center to look for variations: the effects of LOS. Interpreting the oscillation in terms of different wave modes and/or plasma motions always depend on the line of sight as we observe in the limb or on the center of the disk. We will address some of these questions. MDI and TRACE photospheric and UV imaging of TRACE and SPIRIT has been used to acquire simultaneous high temporal and spatial coverage along with the spectroscopic data from CDS. EIT was operated in the shutterless mode to achieve high Cadence.

Physics of sunspot oscillations

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Abstract

The analysis of optical, infrared, radio and UV observations of sunspot oscillations in photosphere, chromosphere, transition region and corona in frames of resonance theory is presented. The relation between 3-min oscillations and umbral flashes is considered. The interplay between 3-, 5-min oscillations and penumbral waves is discussed. The effect of nonblinearity on 3-min oscillations is considered.

Oscillations above the umbra of sunspots

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Abstract

Oscillations above twelve sunspots are investigated with the Coronal Diagnostic Spectrometer (CDS) and the Transition Region And Coronal Explorer (TRACE). The CDS observations give knowledge about the oscillations in the chromosphere, transition region, and corona and information regarding the contributions of different emission lines to the TRACE 171 Å and 195 Å channel intensities. A period close to 3 min is observed above the umbra of each sunspot. The observations give support to the idea that the 3 min oscillations are caused by upwardly propagating acoustic waves. This is evident from the asymmetry of the oscillation amplitudes in the red and blue wings of the emission lines, where the oscillations are decidedly more pronounced in the blue than in the red line wing. Additional support for the acoustic wave hypothesis emerges from the agreement between the observed and predicted relations in phase and magnitude between the oscillations in intensity and line-of-sight velocity. The frequency of the oscillations is above the acoustic cutoff frequency in the umbral atmosphere and the observed phase differences between lines emitting at different temperatures point to an upwardly propagating disturbance.

Numerical Simulation of Non-Linear Oscillations and Shocks in the Solar Atmosphere

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(3) Department of Mathematics,
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Abstract

Recent analyses of TRACE observations of oscillations of coronal loops suggest that these oscillations are driven by underlying perturbations that propagate through the transition region and into the corona. We describe a one-dimensional study of the response of the solar chromosphere and corona, modelled by the Euler equations, to impulsive and continuous sources at the surface. This study compares characteristics of oscillations in the chromosphere, transition region and corona using various models of the atmosphere of the quiet Sun and above sunspots. In particular, these simulations show that 5-minute oscillations occur in the upper chromosphere and in the corona in the quiet Sun model, while 3-4 minute oscillations occur in the sunspot models in accordance with observations. We examine the response to various impulse strengths and the relationship between oscillation amplitude and power spectrum, and discuss how observations of coronal oscillations can be used for seismology of the solar atmosphere.

Posters

Search for lower atmospheric signals of coronal longitudinal oscillations

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Abstract

Longitudinal oscillations aka propagating disturbances, originally seen in SOHO-EIT 171Å and 195Å, have been well observed in TRACE 171Å passband and occasionally observed in the hotter TRACE 195Å passband. Two populations, oscillating in the 3 and 5 minute bands are discerned. The 3 minute population is apparently rooted in sunspots, whilst the 5 minute population is not. Many authors take the existence of both these populations to indicate the presence of slow magnetosonic waves in the solar corona. However, their oscillatory properties lower down in the solar atmosphere are less well known. We examine MDI, Kanzelhöhe and SOHO-CDS data to look for evidence of the existence of these oscillations in the photosphere with regard to their root locations.

Solitary wave propagation from the photosphere into the solar corona

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Abstract

In the present paper we study the excitation and time dependent dynamic evolution of solitary waves on vertically open cylindrical magnetic flux tubes in a stratified plasma. The axisymmetric flux tubes have a typical field strength of 1500 G at their photospheric roots, reducing to 20-30 G in the corona. Solitons are excited by a footpoint driver. The propagation of the solitary signal is investigated by solving numerically a set of fully nonlinear 2.5D MHD equations. We compare our results with the analytical solution of Molotovshchikov and Ruderman (1987). The model is applied to spicule formation in the chromosphere, as suggested by Roberts & Mangeney (1982).

We have also determined, numerically, the threshold value of parameters at which perturbations change from linear to nonlinear. Future possible improvements in modeling and the relevance of the photospheric - chromospheric transition region coupling by spicules is suggested.

Influence of random atmospheric magnetic field on photospheric surface waves

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Abstract

The discrepancies between theoretically predicted and observed frequencies of solar global eigenoscillations (e.g. p- and f-modes) have attracted major attention in the past two decades. In the present paper we wish to explore whether the solar atmosphere may account for the apparent frequency paradox. Magnetic flux is continuously emerging at photospheric levels and is expanding into the solar atmosphere. We investigate the possible effects of an *atmospheric* random magnetic field on the solar fundamental mode (f-mode) characterised by the dispersion relation $\omega^2 = gk$. Frequency corrections due to a stochastic atmospheric magnetic field are derived analytically in the limit of the long wavelength approximation, while these corrections are determined numerically for arbitrary wavelengths.

Random flow effects on surface waves

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Abstract

Studying the properties of surface waves is probably the simplest wave tool for diagnosing a medium. Surface waves are observed e.g. as the fundamental global oscillations (called the f-mode), and have also been detected at the boundaries of various solar structures (e.g. sunspot filaments, coronal loops, coronal funnels, solar wind tubes, etc.). SOHO and TRACE have demonstrated that the solar atmosphere and its magnetic structures are highly inhomogeneous at almost all spatial and time scales. The question naturally arises: does the random nature of the medium influence the propagation characteristics of these surface modes?

In the present paper we investigate the influence of a random velocity field on a plasma surface wave. We derive the correction to the dispersion relation of the surface wave due to the presence of the stochastic plasma flow in the incompressible limit. Frequency corrections due to random flow fields are evaluated analytically in the limit of the long wavelength approximation, while these corrections are determined numerically for arbitrary wavelengths. The derived correction to the dispersion relation may help us to diagnose more accurately solar plasmas.

Buoyancy-induced periodic phenomena in tilted magnetic fields

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Abstract

The nonlinear behaviour of buoyancy-induced periodic phenomena (oscillatory convection, Parker instability) in tilted magnetic fields is studied and potential applications to sunspot penumbrae and moving dipolar features are discussed.

MHD waves in flux tubes : A possible explanation of waves in coronal loops ?

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Abstract

Recent observations of oscillations in coronal loops suggest the presence of slow mode waves in coronal loops with periods of between 3 and 5 minutes. Sound waves of these periods cannot propagate into the corona directly because of the acoustic cut-off frequency. A possible explanation of these waves is the generation of MHD modes lower in the solar atmosphere which are then transmitted along flux tubes, these MHD waves may then couple into slow modes in the corona, hence generating the observed waves. Numerical simulations were performed to test this possibility.

New determination of Solar gravitational moments J_2 and J_4

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Abstract

By using the theory of slowly rotating stars, the solar quadruple and octopole moment, respectively J_2 and J_4 were computed using a solar model obtained from CESAM stellar evolution code (P. Morel et al. (1997)) combined with a new analytical model of solar differential rotation (Corbard et al. 2002) taking into account a near-surface radial gradient of rotation inferred and quantified from MDI f-modes observations by Corbard and Thompson (2001). The values of J_2 and J_4 obtained permit to evaluate the solar oblateness and it's induced latitudinal variations of solar diameter in order to compare them to those obtained from observations. We also use J_2 to calculate its contribution to the advance of the perihelion of Mercury for which the found value is in agreement with the theory of General Relativity and the measurements of Mercury's orbit by means of planetary ranging radar.

MAG Waves in Sunspot Umbra: Damping properties and Slow mode leaking to the Corona

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Abstract

The linear oscillations of a stratified atmosphere embedded by a uniform vertical magnetic field are studied here. We use a simple theoretical model, formed by the superposition of two isothermal layers, representing respectively i) the photosphere and the chromosphere and ii) the corona. The bottom layer behaves for some modes as a resonant cavity where MAG waves are semi trapped. We find the existence of two types of modes: 1) Fast modes which are trapped below the transition layer 2) Mixed modes which are resonant modes in the first layer and leaking part of the energy to the corona. These last modes have been found to be damped in the horizontal direction and can explain the observed slow modes in the corona .

Session 2: Waves in the Chromosphere

Invited Review

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Abstract

Invited Review

????

Abstract

Oral Contributions

COmospheric Waves

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Abstract

The COmosphere is a cool layer ($T \sim 3500$ K) thought to extend from the upper photosphere several hundred kilometers into the warm middle chromosphere ($T \sim 7000$ K). The main observational signatures of the COmosphere are the anomalous limb darkening of the strong 5μm rovibrational bands of carbon monoxide, and the curious off-limb emissions of the same species. The origin, spatial pervasiveness, and physical significance of the region have been hotly debated over the past several years. Although the nature of the COmosphere remains to be settled, one thing is clear: at disk center, the strong CO lines achieve $\tau \sim 1$ in the high photosphere, and thus are sensitive to the wave energy propagating up through that region, ultimately into the chromospheric "canopy" above. I describe time-resolved measurements of the infrared CO lines obtained at the 1.5 m McMath-Pierce telescope at Kitt Peak, using a new adaptive optics (AO) system, developed by C. Keller and C. Plymate, and an integral field unit (IFU) based on a 4mm×4mm Bowen-style image slicer designed by K. Pierce in the 1960s. The IFU allows a $10'' \times 10''$ area on the Sun to be spectrally imaged in a single exposure with the 256×256 Amber Engineering InSb camera, while the AO system mitigates atmospheric blurring. The sharpest frames are selected after the fact, and assembled into a 2-D spatial time series of CO parameters: line core temperatures, widths, and Doppler shifts. I present the results of several recent exploratory IFU/AO runs, whose purpose was to probe the acoustic disturbances that are thought to give rise to Ca II "K grains." This provides an important boundary condition for the dynamical fine structure seen at higher altitudes by *SoHO* and *TRACE.*

Evidence for wave dissipation through EUV emission line narrowing

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Abstract

Using long-duration observations over closed field, quiet Sun regions above the solar equator, evidence has been found for the narrowing of coronal emission lines with increasing altitude. This is interpreted as evidence for wave dissipation in the quiet Sun corona.

Detectability of high frequency acoustic waves with TRACE

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Abstract

High-frequency acoustic waves have been proposed as a mechanism to heat the Solar chromosphere in internetwork regions. Such waves are difficult to detect using ground based observations because of seeing. Space based Solar observatories like SOHO and TRACE are not hampered by such high frequency disturbances caused by the Earth's atmosphere. We have used detailed NLTE radiation hydrodynamic simulations to investigate the detectability of high frequency acoustic waves with TRACE. A broad spectrum of acoustic waves are fed into the computational domain at the lower boundary of the model atmosphere and TRACE UV continuum intensities are calculated by folding the derived intensities with the TRACE filter functions for the 1600 and 1700 filters. Phase diagrams are calculated and compared with the acoustic spectrum in the simulations. The results show that the width of the TRACE intensity response functions limit the possibility of detecting the high frequency signal. Furthermore, long wavelength leakage into the filters introduces shifts in the phase diagrams. Proper linear combinations of the filtergrams can minimize these effects.

MHD wave propagation in open flux tubes in the low solar atmosphere

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Abstract

The propagation of wavelike disturbances in open magnetic flux tubes in the low solar atmosphere is considered. Their evolution is studied numerically in a fully non-linear 1.5D MHD regime under the thin flux-tube approximation and includes an approximate treatments of radiation, thermal conduction and other energetics. In particular, the slippage between ion species, which are directly affected by changes in magnetic and electric fields, and the neutral fluids, which are affected only indirectly by colliosional coupling, is considered. This becomes non-negligible in the upper chromosphere for high frequency Alfvén waves (typically for frequencies of the order of 0.1 Hz) and the resulting wave damping and dissipation is included in our treatment. The disturbances are generated in the photosphere or low chromosphere by a variety of localised drivers, including Alfvén wave, slow wave and random drivers, and over a wide range of parameters. Comparison is drawn with observed solar phenomena, particularly solar spicules.

The upper solar chromosphere observed with SUMER

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Abstract

The chromospheric network reflecting the supergranulation of the outer convection zone of the Sun is a prominent feature of the lower solar atmosphere that extends into the transition zone between chromosphere and corona. In particular, the physics of the so-called "non-magnetic" chromosphere in internetwork regions is not yet fully understood. We present observations of the H I Lyman continuum obtained in areas of the undisturbed Sun by the Solar Ultraviolet Measurements of Emitted Radiation (SUMER) instrument on the Solar and Heliospheric Observatory (SOHO). The observing sequences are unique in the sense that they cover the spectral range from 67 nm to 93 nm with the highest cadence the SUMER spectrometer can achieve operating near the limit of its mechanism performance, telemetry allocation, and memory capabilities. In this wavelength range not only the Lyman continuum but also many extreme-ultraviolet emission lines (N II, N III, S IV, O II, O III, O IV, O V, Ne VIII, and Mg IX) are prominent, allowing the investigation of radiation formed at temperatures representative of regions from the chromosphere to the corona. Brightenings have been identified that are presumed to be related to the well-known 3 min oscillations as seen, for instance, in Ca II H_{2v} and K_{2v} observations. The relative temporal variations of the continuum radiance near 77 nm were typically 20 % to 40 %, whereas simultaneously recorded transition-region lines varied by about 40 % of their lowest values in phase with the continuum. In the corona, the Ne VIII and Mg IX lines with formation temperatures of 620 000 K and 950 000 K, respectively, experienced relative changes of $\approx$ 10 % and displayed no phase relationship with the transition-region lines or the continuum. The observations will be discussed with a view towards providing constraints for modelling chromospheric structure and dynamics.

A Search for High Frequency Oscillations with TRACE

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Abstract

A very high cadence sequence of TRACE UV images is used to search for high frequency (>10 mHz) oscillations in the solar chromosphere. We observed an active region near disk center and analysed intensity time sequences of the plage/network and internetwork. We find in most cases statistically significant peaks are present in the power spectra between 10 and 20 mHz. In exceptional cases we find power peaks at even higher frequencies, corresponding to period as low as 15 – 30 sec.

Wave Propagation in the Internetwork Chromosphere

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Abstract

Calcium bright points in the internetwork chromosphere have been shown by numerical simulations of their dynamics to be caused by large-amplitude acoustic waves that form shocks in the layers of formation of the emission peaks of the Ca II H and K lines. The density of the bright points is of the order of 10 or 20 per supergranulation cell. Except for supergranular flow, they maintain fixed locations. Their filling factor increases upward in the chromosphere, suggesting an origin in point-like sources in the photosphere. The acoustic waves emanating from these source regions travel upward in cones with an opening angle of about 90°.

This topology explains why numerical simulations of the dynamics reproduce the characteristic and defining features of calcium bright points but fail to provide quantitative agreement with observatio ns.

Posters

Propagating waves in the chromosphere with frequencies below the acoustic cut-off

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Abstract

Theory suggests that oscillations with frequencies below the acoustic cut-off frequency can propagate into the chromosphere. If true, the 5 min oscillations could play a substantial role in the transport of acoustic energy into the chromosphere. Our recent simultaneous observations of the velocity wavefield in photosphere and chromosphere lend some support to this theory. We have detected upward travelling waves at frequencies as low as 3.5 mHz in sunspots and plage regions. However, these waves are not present in all active regions at all times. This suggests that there must be at least one other factor, besides the presence of magnetic activity, to enable propagation of low frequency acoustic waves. Maps of the wave travel time in the chromosphere offer a tool to find these factors and to constrain the models for active regions as well as quiet sun. At higher frequencies (6-8 mHz) we find upward propagating waves in the quiet sun, while waves in active regions are mostly evanescent-like, with some small areas showing upward and downward wave propagation. We will discuss some of the implications of these observations.

A Wavelet Analysis Approach to TRACE quiet Sun oscillations

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Abstract

An automated wavelet analysis approach to TRACE UV quiet sun datasets is discussed. Periodicity and duration of oscillations present in the network and internetwork are compared and contrasted. This provides a means of extending previous Fourier results into the time-localised domain. As expected the longest duration oscillations occur around the acoustic band and the network tends to dominate over the internetwork at periods > 4 mins. However, it is shown that the internetwork can dominate over the network at long periods (7 – 20 mins), but only for short durations (< 3 complete oscillations). A new heating mechanism is suggested to explain these results.

Oscillatory Signatures Above Quiet Sun Magnetic Elements

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Abstract

An area of quiet Sun was studied in the 1998 May 16 data set of JOP072 (Joint Observing Proposal between *SoHO* and *TRACE*). This 130 min time–series was complemented by simultaneous ground–based observations obtained at NSO/Sacra mento Peak – consisting of photospheric vector–magnetograms and Ca II H l ine & wing spectra. We present results from wavelet analysis performed on magnetic regions and relate these to possible wave modes in the solar atmosphere.

Evolution of blue-shifted Hα grains observed in the cell interior

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Abstract

We studied temporal variation of Hα blue-shifted grains in the cell interior and found causal relation between Hα line broadening and upflow in the chromosphere. Our analysis is based on filter images at -0.6Å from the Hα line center and Hα spectra obtained simultaneously with Domeless Solar Telescope(DST) at Hida Observatory. A quiet region near the disk center was observed for 80 minutes in good seeing condition on 8 August 1995.

Hα grains appear as round dark features in Hα-0.6Å images, and their typical diameter and duration are 10^3km and 1 minute respectively. In some cases, they repeatedly appeared at the same location with interval of 3 minutes. On the other hand, dark mottles on the network show elongated shapes and have longer durations(>5 minutes).

Doppler velocity is derived from Hα spectra, and the result shows 3-minute oscillation of large amplitude(8 km s^{-1}) at the location of grains. Although 3-minute oscillation is common to the chromosphere of cell interior, Hα grains indicate the location of amplified oscillation. Hα line broadening is detected at the location of grains, and it is found that the maximum broadening occurred just before the upward velocity reached its maximum. The broadening of Hα line indicates the existence of shock or turbulence in the chromosphere, which causes the following upflow. The periodic behaviour of grains suggests that the 3-minute oscillation in the chromosphere produces or triggers the shock.

Profile Variations of Chromospheric Bright Points

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Abstract

Large-amplitude oscillations in the intensities of chromospheric lines are found at discrete locations in the interior of supergranulation cells. They are formed by upward-propagating acoustic waves and are observed in the Ca II H and K lines as brightenings with a typical period of 3 min. Changes in the values of the emergent intensities and frequency shifts in the emergent line profile reveal the temperature fluctuations due to the upward-propagating waves and the state of motion of the atmosphere.

Comparison of observed time-varying H line profiles with the profiles from simulations of the d ynamics shows broad agreement in the characteristic features of the bright-point phenomenon but indicates significantly lower peak temperatures as well as lower velocity shifts than in the dynamical model of Carlsson and Stein.

Moreton waves observed at Hida Observatory

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Abstract

Moreton waves are flare-associated waves observed to propagate across the solar disk in Hα, especially in the wing of Hα. The phenomenon was first reported in 1960 by Moreton. They propagate at speeds of 500–1500 km s^{-1} with arc-like fronts in somewhat restricted angles, and are often associated with type II radio bursts. Uchida in his 1968–1974 papers nicely explained Moreton waves as the intersection of a coronal MHD fast-mode weak shock wave and the chromosphere. However, the generation mechanism of a Moreton wave has not been made clear yet. The Flare Monitoring Telescope at the Hida Observatory of Kyoto University observed 13 events associated with flare waves (i.e. Moreton waves and/or filament oscillations) in Hα from 1997 to 2002. We review our studies of Moreton waves based on these observations;

(1) relation between EIT wave and Moreton wave (Eto et al. 2002),

(2) simultaneous observations with X-ray wave (Narukage et al. 2002),

(3) three dimensional structure of Moreton wave (Narukage et al. 2003a),

(4) relation with filament eruption (Narukage 2003b). In all events, filament eruptions were observed. Especially, in the case when the propagation of the Moreton waves was observed, the filaments erupted in the same direction after the waves propagated. We consider this point as the clue to elucidate the generation mechanism of the flare-associated wave.

Collisional and viscous damping of MHD waves in partially ionized plasmas of the solar atmosphere

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Abstract

Magnetohydrodynamic (MHD) waves are widely considered as a possible source for heating of various parts of the outer solar atmosphere. The heating effect of MHD waves is connected with a certain dissipation mechanism which converts the energy of damped MHD waves into the energy of the background plasma. The presence of neural atoms in the partially ionized plasmas enhances the dissipation of energy of the propagating MHD waves.

In application to the processes in the solar photosphere and chromosphere damping of MHD waves is considered by different authors taking account of two different energy dissipation mechanisms. As the main mechanism of the MHD wave energy dissipation one group of researchers assumes the ion-neutral collisions which cause the friction between ions and the neutral fraction in the partially ionized plasma (Piddington 1956; DePontieu et al. 2001). At the same time, an other group of authors takes into account only the viscosity effects (Tsiklauri & Nakariakov 2001; Ofman 2002). We emphasize, in that connection, different physical nature of the above two mechanisms of MHD wave energy dissipation. The forces associated with the viscosity have purely kinetic origin and are caused by the momentum transfer during the thermal motion of particles, whereas the collisional friction forces appear due to the averaged relative motion of the plasma species.

While the frictional dissipation (electrical resistivity) can usually be safely neglected as compared to the viscosity effects in the fully ionized solar corona, the relation and mutual role of both these dissipation mechanisms for damping of MHD waves in the lower (partially ionized) solar atmosphere requires a special comparative study. Correct description of MHD wave energy dissipation requires in general case the consideration of both mechanisms via inclusion of appropriate terms into the advanced form of the generalized Ohm's law, as well as into the momentum, energy and induction equations. In this paper we give some basic estimations concerning the frictional and viscous damping of MHD waves in the solar plasmas and decide which dissipation mechanism and where can be considered as a dominating one,

as well as define the cases where both mechanisms should be taken into account.

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Ofman, L., 2002, ApJ, 568, L135.

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Session 3: Topological changes and magnetic Coupling

Invited Review

K. Schrijver
LMSAL (USA)

Abstract

Invited Review: Topological changes and magnetic coupling: observational aspects

S.K. Solanki
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Abstract

The magnetic field, which possesses a complex structure in the solar atmosphere, is the prime agent coupling the different layers of the atmosphere with each other. The topology of the coronal field is determined by the emergence of new field into the solar atmosphere from the subsurface layers, the subsequent interaction of the footpoints of this field with convection and the interaction of the freshly emerged loops with the overlying ambient field. Various processes cause the magnetic topology to change, often accompanied by energy release.

An overview of the observational evidence for such magnetic coupling of the solar and topological changes is provided.

Oral Contributions

Outflow in equatorial coronal holes and the origin of the fast solar wind

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Abstract

The outflow velocity maps of the Ne^{7+} ion have been deduced from Doppler shifts of the Ne VIII 770 Å line (with a formation temperature of about 630 000 K), which was observed by SUMER/SOHO in equatorial coronal holes. By comparison with the photospheric magnetic field measured by NSO/Kitt Peak, it has been found that the topology of the Dopplergrams is obviously determined by that of the underlying magnetic field. Red shifts or weak blue shifts are present only in bright structures seen in the intensity maps of the Ne VIII line, with mixed-polarity magnetic structures underlying. Conversely, large

blue shifts are mainly associated with dark regions, where strong magnetic flux of a single polarity is concentrated. It seems that the results are in agreement with the notion that the fast solar wind originates from, and is initially accelerated in, the open magnetic funnels. The measured outflow velocities in the central regions of the network are comparable with the values predicted by models, in which coronal heating was considered as being due to cyclotron damping of high-frequency Alfvén waves.

Jets and Alfven waves generated by magnetic reconnection in the corona

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(2) Kwasan Obs., Kyoto Univ. (Japan)

Abstract

The generation of jets and Alfven waves by magnetic reconnection in the corona is discussed. Through the MHD simulations, we found that part of the magnetic energy released by reconnection is converted to the Alfven and the fast-mode MHD sonic waves.

Coronal loop heating by high frequency Alfvén waves

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Abstract

We propose a new coronal loop heating scaling law based on the resonant interaction between high frequency Alfvén waves and the coronal plasma. Such resonance occurs whenever the frequency of the waves matches the local proton gyro-frequency, and results in the conversion of wave energy into plasma thermal energy. Our scaling law is derived using a simplified heating function expected from this mechanism. We test it against observations of soft x-ray quiescent loops and discuss the constraints that the observations place on the properties of the waves.

TRACE downflows and energy release

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(2) Department of Earth and Planetary Science,
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(3) Nobeyama Radio Observatory,
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Abstract

We have examined in detail the evolution of a big two-ribbon flare which occurred on 2002 July 23. The extreme ultraviolet images obtained with TRACE show dark downflow motions (sunward motions) above the post-flare loop, not only in the decay phase but also in the impulsive and main phase. We found that the times when the downflow motions are seen correspond to those of the bursts of nonthermal emissions in hard X-ray and microwave. This result means that the downflow motions occurred when strong magnetic energy was released, and that they are, or correlated with, the reconnection outflows. We also found the ascending motions of super hot plasma region seen in TRACE and RHESSI associating with the light curves in hard X-rays and microwaves. This result supports the Neupert effect.

The finest features in the EIT images

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(2) Theoretical Physics Institute, UCL,
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Abstract

From the images of the Extreme ultraviolet Imaging Telescope, we carefully extract the smallest objects on the base of an advanced directional wavelet algorithm. Observational and instrumental biases are corrected for. Several categories of fine features are distinguished: EUV bright points, thin loops, footpoints, point-like solar structures, cosmic-ray hits, etc. The measured parameters are analysed physically, and statistical trends are exhibited in the course of the solar cycle.

Posters

On the Nature and Location of Large-scale Coronal Pulse Propagations

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Abstract

"EIT waves" are generally associated with low-cadence, full-disk 195 Å EUV observations. Recent TRACE data allow us to see these propagating coronal waves in more than one narrowband filter and with high spatiotemporal resolution. With new mapping algorithms, we can track such wavefronts in a reproducible manner, and determine the density changes and flux associated with the propagation.

We examine in detail an event from 13 June 1998. Using only observational evidence, we find that the wavefront behaves as a fast-mode magnetoacoustic wave. It also appears that the wave experiences adiabatic compression, and does not lose any measurable energy to the surrounding medium.

Through comparison of 171 and 195 Å EUV passbands and examination of wave dispersion, we are able to place limits on the altitude of the propagation. We compare these limits with existing theories, and with results from our own analytical analysis. Results suggest that the "EIT wave" is trapped in a wave guide in the lowest part of the corona.

Using our postulation, we offer a possible explanation for the dearth of soft x-ray observations of propagating waves, as well as the seeming uniformity of EUV events. In light of such propagation constraints, we address the usefulness of such waves in coronal seismology.

A Simple Topological Model of Bastille Day Flare (2000, July 14)

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Moscow (Russia)
(2) D.V.Skobel'tsyn research institute of nuclear physics
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Abstract

We present results of three-dimensional mumerical modeling of the coronal magnetic field in the active region NOAA 9077, where a large two-ribbon flare (3B/X57) occured on 2000, July 14. The coronal field was reconstructed using a potential approach on the base of photospheric magnetograms obtained by the SOHO/MDI. An analysis of the computed stucture is performed. Two-ribbon nature of the flare observed in different wavelengths by spacecrafts Yohkoh and TRACE, is shown to be a consequence of the field topology. A place and a form of bright chromospheric ribbons and the apparition of bright kernels along the edges of ribbons are explained. Note that the advantage of our model consists in the simplicity and the clearness.

Topological changes of the magnetic network as seen in different UV/EUV emission lines

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Abstract

By combining observations made by SUMER and MDI aboard SOHO, fine structures in equatorial coronal holes have been studied, in particular the relationship between the ultraviolet emission line parameters (line radiance, Doppler shift and line width) and the underlying magnetic field. The bases of coronal holes seen in chromospheric lines have generally similar properties than normal QS regions, i.e., small bright points are the predominant features in the network as well as in cell interiors. An obvious difference has been found in the shape of the H I Ly β line, which has very asymmetric (skewed towards the blue side) profiles in the coronal hole. On the other hand, loop-like structures are the most prominent features in the transition region. In coronal holes, we found that most of such structures seem to have one footpoint rooted in the intra-network and to extend into the cell interiors. Some of them appear as star-shape clusters. In Dopplergrams of the O VI line, fine structures with apparent blue shifts are also present, although they are on average red shifted. Structures with blue shifts have usually also broader line widths. They seem to represent plasma above large concentrations of unipolar magnetic field, without obvious bipolar magnetic features nearby.

Session 4: Waves and Oscillations in Prominences

Invited Review: Theoretical aspects of waves and oscillations in prominences R. Oliver

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Abstract

Although the existence of solar prominences has been known for more than a century, the present understanding of their internal structure and physical properties is far from satisfactory. An alternative way of obtaining more information on the nature of these objects consists of exploiting the fact that prominence material oscillate after being disturbed. The result is a new discipline (called *prominence seismology*) in which observational results, such as the period, wavelength, spatial distribution of oscillations, etc., and theoretical studies, based on the normal mode vibrations of prominence equilibrium models, are compared. Here, the main theoretical advances made so far are reviewed.

Invited Review: E. Wiehr

Germany

Abstract

Oral Contributions

Damping of standing Alfvén waves due to the resonant generation of slow magnetosonic waves

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Abstract

It is shown that the periodic shearing motions at the velocity antinodes of the standing Alfvén waves are unstable to the compressible perturbations. As a result the slow magnetosonic waves with the half frequency of Alfvén waves grow exponentially in time. It leads to the damping of Alfvén waves. The damping time is proportional to the amplitude of the Alfvén waves. The phenomenon can be of importance in the solar atmosphere.

Dynamics of coronal loops: "Catastrophic cooling" and high-speed downflows

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Abstract

In this work, we address the question of plasma condensation and "catastrophic cooling" in long coronal loops. We carried out numerical calculations of coronal loops and find several classes of time-dependent solutions (static, periodic, irregular), depending on the spatial dependence of a *temporally constant* energy deposition in the loop. One of these classes is in remarkably close agreement with the features observed with the Transition Region And Coronal Explorer, TRACE, described by Schrijver (2001)[1]: Emission in C IV 1548 Å, developing initially near the loop tops, cool plasma sliding down on both sides of the loop, downflow velocities of up to 100 km/s, and a downward acceleration which is substantially reduced with respect to the solar surface gravity. In contrast to earlier models, we suggest that the process of catastrophic cooling does not ha ve to be initiated by a drastic decrease of the loop heating. It can also result from a loss of equilibrium at the loop apex which is a natural consequence if the loop is heated predominantly at the footpoints, but *constant* in time.

[1] C. Schrijver, Solar Physics **198**, 325 (2001)

Fast Magnetohydrodynamic oscillations in multifibril Cartesian systems

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Abstract

Observations of quiescent filaments show very fine structures suggesting that they can be composed by small-scale threads or fibrils and, on the other hand, two-dimensional, high-resolution observations have pointed out that individual fibrils or groups of fibrils may oscillate independently with their own periods. Using Cartesian geometry, Díaz et al. (2001) studied the fast magnetohydrodynamic oscillations of a single and isolated prominence fibril showing that for reasonable values of the fibril's width the perturbations extend far away from its axis. This study can be looked at as incomplete since, by considering only one fibril, the interaction between the different fibrils composing the prominence was not taken into account. In this work, we study the fast MHD modes of oscillation of homogeneous and inhomogeneous multifibril Cartesian systems trying to represent the oscillations of the fibril structure of a real prominence. In the case of an homogeneous multifibril system, our results show that, for a realistic separation between fibrils, the only surviving mode is the symmetric one, which means that, at the end, all the fibrils oscillate in spatial phase with the same frequency. An inhomogeneous multifibril system can be obtained by varying the Alfvén velocity within each considered fibril, and the results show that there are not symmetric or antisymmetric modes, that the amplitudes of oscillation are higher in the more dense fibrils, that the frequency of oscillation of the fibrils, due to the only non-leaky mode, is slightly smaller than that of the dominant fibril considered alone, and that all the fibrils oscillate in phase. Finally, the introduction of a k_y wavenumber results in a better confinement, a lower interaction between fibrils and a decrease in frequencies.

Posters

Damping of compressional waves in prominences

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Abstract

The present poster aims to review some of the dissipative effects (isotropic and anisotropic viscosity, anisotropic thermal conduction, electrical resistivity, radiative damping) which may count for damping of compressional MHD waves in solar prominences. Our theoretical results are compared with recent observations of wave attenuation in quiescent prominences.

Session 5: Transition Region Dynamics: Transients, jets

Invited Review: Transition region dynamics

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Abstract

The transition region structure and dynamics appear to be controlled by the underlying magnetic field and its evolution. Energy is transferred from the photosphere through the transition region to the corona. The rapid brightenings and small plasma jets observed with UV imagers and spectrometers result from rapid energy release, most probably magnetic reconnection, in an atmosphere permeated by loops of different size and orientation. We will review signatures of energy release in the photosphere and chromosphere and evidence of the subsequent shocks and plasma waves in the transition region.

Invited Review: Transients and Jets Observed in the Transition Region

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Abstract

Small scale releases of energy (nanoflares) have often been implicated as a coronal heating mechanism. There are many observations of such energy releases, usually in spectra and images that are sensitive to temperatures around 1 $\times 10^5$ K, but there is little understanding of how the observed transients are related to coronal heating. In this talk, I will review the previous observations of transition region transients and jets and discuss their energetic implications.

Oral Contributions

MHD Shocks and the Origin of the Solar Transition Region

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(2) Lockheed Martin Solar & Astrophysics Laboratories
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Abstract

Simultaneous observations of the solar atmosphere from its surface to the corona obtained with the Solar and Heliospheric Observatory (SOHO) and Transition Region and Coronal Explorer (TRACE) show a ubiquitous sequence of events that start from cancellation of photospheric magnetic fields, pass through shock formation and result in transition region supersonic jets and microflares. These results support a novel view of the energy build up in the solar atmosphere associated with cascade of shock waves produced by interacting network magnetic elements in the photosphere and provide insight into the origin of the solar transition region. The findings account for the general mechanisms of energy production, transfer and release throughout the Sun's and stellar atmospheres.

Intensity variations in EIT shutterless mode: waves or flows?

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(2) Royal Observatory of Belgium, Ringlaan 3, Brussels, Belgium

Abstract

The EIT high-cadence synoptic program aims to monitor long-term changes in the small-scale dynamics of all types of solar structures, using high-cadence sequences made by the Extreme-ultraviolet Imaging Telescope (EIT). Every 3 months, 120 EIT-images of a quarter-disk are taken in shutterless mode, allowing for a time cadence of 68s. The sequence is taken alternately in two bandpasses, 304Å and 195Å. The program is supported by TRACE (171Å) and by additional instruments like CDS, MDI, etc. whenever possible.

The EIT 304Å sequence taken on 11 July 2001 reveals 3 very interesting features: bright feat ures move along the spine of an interesting filament, an off-limb loop structure expands and brightens up and as most prominent feature, a bright propagating disturbance moves down along an off-limb loop structure. The multiwavelength study of the 11-July-sequence reveals that the expanding loop region is directly related to a C2.4 flare seen in SXT with interesting flare loops in EIT and TRACE. The intensity variations off-limb seem to be only observed in EIT 304Å and slightly in TRACE 171Å. In order to interpret these as waves or flows, we follow the method used by Wiik et al. 1996 in their analysis of bright 'blobs' moving down along postflare loops in H alpha. We identify the 7 blobs with highest intensities and follow them on their way down the loop. By means of a location-time plot, bulk velocities can be measured at several locations along the loop. The velocity curve found this way is then compared with the characteristic wave speeds and the free fall speed in order to derive the nature of the intensity variations. Additional information on density and temperature is gathered by measuring the relative intensity enhancements and comparing the EIT 304Å sequence with Big Bear data and 171Å data. The combination of all these constraints give us an interesting view on the nature and origin of the intensity variations but still several hypotheses are possible.

Analysis of intensities, line widths and line shifts during blinkers

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Abstract

Quiet regions at Sun centre were observed using SUMER/SOHO. Relations between variations in the intensity, line width and line shift during a blinker event are studied. We show results of the analysis of the C II 1037 Å ($2-4\cdot10^4$ K), O V 629 Å ($2.5\cdot10^5$ K) and O VI 1038 Å ($3\cdot10^5$ K) transition region lines. The preliminary results show that there exist different classes of blinkers depending on the evolution of the light curve and Doppler shifts during a blinker event. We will also use model calculations in order to understand the physics behind the different observational classes of blinkers.

Intense Transition region brightenings in active regions

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Abstract

There is a class of transition region brightenings found in active regions that can be 20–100 times brighter than average quiet Sun intensities. The Coronal Diagnostic Spectrometer on SOHO is uniquely capable of simultaneously measuring the abundance, density and temperature structure of such brightenings, and a summary of their properties will be described.

Episodic coronal loop heating

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Abstract

Coronal loop temperatures are known to be of a few millions degrees but the nature of the energy source remains as a longstanding fundamental problem for solar (and stellar) physics. Observations of solar atmospheric plasma show clear evidence of frequent very localised heating events, which may statistically responsible for heating of the solar upper atmosphere. One heating theory indicates that these micro-scale events are driven by localised magnetic field reconnection. In this paper, we present the results of numerical calculations that describe the response of the coronal plasma to small-scale heating pulses in a magnetic loop. In particular, we study the effects of energy input pulses injected randomly near the two footpoints of a semi-circular loop. We have found that increasing the elapsing time between successive pulses, the overall loop temperature decreases. When a critical elapsing time is reached the loop can no longer be maintained at typical coronal temperatures. These features have some support from SOHO-CDS observations of coronal loops which seem to undergo strong variability especially in active regions of the solar atmosphere (Kjeldseth-Moe & Brekke, 1998). We also have found that successive random pulses can statistically maintain the average plasma temperature at typical coronal values. Due to the randomness of the heat injections, the resulting temperature profiles show thermal bumps that could be connected to intermittent behaviour in the transition region and the low corona.

Observations of Blinkers with SOHO/CDS and TRACE

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Abstract

Blinkers are short lived intensity enhancements that are observed in the EUV transition region line s. They were discovered and manually detected using by Harrison (1997) using SOHO/CDS data. We presen t properties of blinkers identified in TRACE C IV data and compare these with blinkers identified in CDS O V. A preliminary study of the corona above blinkers is also presented.

Posters

Short duration active region brightenings observed in the EUV and Hα by SOHO/CDS and HIDA/DST

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(2) Rutherford Appleton Laboratory, Didcot, Oxon. (UK)

Abstract

We present the first detection of an Hα counterpart to the EUV blinker. The observations come from a coordinated campaign between the Hida Observatory, Domeless Solar Telescope (DST) and the SOHO Coronal Diagnostic Spectrometer (CDS) conducted in July and August, 2002. Utilising studies designed for high cadence observations, many short duration brightenings ($<$ 5 mins.) were identified in the He I 537Å and OV 629.732Å spectral lines in CDS data of active region NOAA10039/10044. These brightenings show similar characteristics (intensity increases, sizes) to longer duration EUV blinkers previously reported in active regions and the 'quiet' Sun. Focusing on several events which show pronounced emission in the upper chromosphere (He I), we have been able to identify cospatial bright points in the lower chromosphere (H α centre, $\pm$0.5Å) which show enhanced emission during the EUV blinker. These bright features have similar lifetimes to their EUV counterparts and their peak intensities occur close to simultaneously with the peak blinker intensities in the He I and O V lines. In most cases the He I and O V lines show downward relative velocities ($<$ 60 km s^{-1}) and excess line broadening at the peak of the event. A statistical study is being performed to determine whether these are common events or confined to specific blinkers with pronounced He I emission. The spatial- and temporal- relationships between the brightenings indicate a causal link between the EUV and Hα "blinker".

Transition region and coronal loops heated by turbulence

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Abstract

A two fluid steady-state dynamic coronal loop model including transition region is presented. It is assumed that an Alfvénic turbulence is responsible for the coronal heating. Alfvén wave energy in large scales is cascaded to high frequency small scales where the wave energy can be readily absorbed by the proton gas. The Coulomb coupling between protons and electrons efficiently heat the electron gas. The model can simulate a fairly uniform or an extremely nonuniform heating along a coronal loop depending on the driving scales of the turbulence. When a realistic level of wave motion and turbulent driving scales are used, the model readily reproduces electron densities of $1 - 4\times10^9 \mathrm{cm}^{-3}$ and electron temperatures of $1 - 3\times10^6$ K in coronal loops. We found hot loops can support moderate steady flows as fast as 30 km/s and high electron densities while cold loops can only support very slow mass flows (close to hydrostatic) and low electron densities.

Condensation in cool coronal loops and its effect on transition region lines

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Abstract

We report numerical calculations of the condensation of plasma in short coronal loops, which has several interesting physical consequences. Firstly, we propose a connection between small, cool loops, which presumably constitute the solar transition region, and prominences in the sense that the same physical mechanism governs their dynamics, namely the onset of instability and runaway cooling due to strong radiative losses. Secondly, we show that the temporal evolution of these loop models exhibits a cyclic pattern of chromospheric evaporation, condensation, motion of the condensation region to either side of the loop, and finally loop reheating with a period of 4000 – 8000 s for a loop of 10 Mm length. Thirdly, we have synthesized transition region lines from these calculations which show strong periodic intensity variations, making condensation in loops a candidate to account for observed transient brightenings of solar transition region lines. Remarkably, all these dynamic processes take place for a heating function which is *constant* in time and has a simple exponential height dependence.

The periodicities of coronal mass ejections

Ahmed Abdel Hady
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Abstract

SUMER, UVCS and LASCO observations of small-scale ejecta

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Abstract

During the fall 2002 SOHO-Sun-Ulysses quadrature, coordinated SUMER/UVCS observations were carried out off of the west limb. Data were acquired over six consecutive days in several lines formed in the 2 10^4 – 10^6 K temperature range. The center of the SUMER slit was placed around 1.14 $R_\odot$ and oriented in the north-south direction, while the UVCS slit was set tangent to the solar limb at altitudes ranging between 1.6 and 2.1 $R_\odot$. On November 19 and 20 SUMER observed repeated transient events characterized by a strong increase of the intensity of transition region and Hydrogen Lyman alpha and beta lines with large line broadenings and line of sight velocities, while little if any variations is seen in lines formed around 10^6 K. The duration of these events varies between 10-15 minutes up to 1 hour. The physical parameters of the SUMER events are presented here. The events observed at low altitude by SUMER and EIT can be later traced as streamer-like outflows seen in LASCO images and UVCS spectra. The relationship between the activity in the high corona and the transient phenomena observed at lower levels by SUMER is discussed.

Repetition of explosive event

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Abstract

We present several examples of explosive events that occur repeatedly near the same location on the Sun. Observations were detected by SUMER in the Si IV line on the quiet Sun near disk center. Three regions of $\sim 7 \times 120$ arcsec^2 were rastered rapidly with a time cadence of $\sim$30 s, each for half an hour. We found that the repetition sites are near regions of photospheric magnetic field evolution. The character and structure of events change during repetition sequences. In some cases, we see evidence for loop-like structure. Although not all explosive events repeat, the repetition nature turns out an important characteristic.

Blinker vs. Explosive events

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Abstract

The structure and dynamics of the transition region from the chromosphere to the corona is crucial for understanding the heating processes of the corona. This very thin layer is highly variable down to the shortest observable time scales. Two prominent phenomena are sticking out: Explosive events, bi-directional jets lasting for less than a minute, and EUV-blinkers. The nature of the latter ones and especially the relation of the two phenomena is still unclear.

We will present new observational evidence that (at least many) blinkers are driven by different physical processes than explosive events. This is based on first detailed spectroscopic investigations of the line profiles during a blinker using SUMER/SOHO. We will also present a 1D loop model to investigate a possible scenario of a blinker being due to a strong flow through a loop. This flow could account for the filling of the loop with dense plasma leading to the observed increase in line intensity.

High cadence, multiwavelength observations of a small flare

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Abstract

The ultimate origin of small scale transient events in the solar atmosphere, and up to which point the same mechanisms are at work in large and small solar flares, remain questions of great interest. We will present high-cadence (few s) multiwavelength observations of a very small flare occurring on Aug. 11, 2002. A large set of instruments allowed a comprehensive sample of the phenomenon at different heights in the atmosphere. In particular, we will present the global view provided by GBO images and spectra, TRACE 171 Å images, SOHO-CDS spectra, RHESSI images and light curves. A preliminary analysis shows an interesting pattern of rapid chromospheric velocity variations temporally and spatially well correlated with hard X-ray signatures, a feature up to now observed only in very large flares.

On Mutual Relation of the Outer Atmospheric Layers in Network: SOHO/CDS and TRACE Study

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Abstract

SOHO/CDS and TRACE measurements of emission in the network of the quiet solar atmosphere near disk center were used to derive a mutual relations of emission and dynamics in different temperature regimes in/above supergranular network. Cross-correlation functions of the intensities and the Doppler shifts of the chromospheric line He I 584.3 Å, transition region line O V 629.7 Å and the coronal line Mg IX 396.1 Å were calculated in order to study the relative variability of different atmospheric layers. Relatively high correlations were found between the intensities and the Doppler shifts of the He I and O V lines with two peaks of the intensity correlation function. The maximum value of the correlation coefficient ($cc = 0.86$) was reached for the zero time lag and the second maximum ($cc = 0.78$) was obtained for the time lag −190 s (O V leads He I). Only one sharp peak ($cc = 0.55$) was detected in the Doppler shift correlation function of these lines for the zero time lag. For the correlation of O V and Mg IX intensities one peak ($cc = 0.57$) of the correlation function was also discovered for the time lag +150 s (Mg IX falls behind O V). Contrary no correlation was obtained for the Doppler shifts of the O V and Mg IX lines. TRACE Fe IX 171 Å images, taken simultaneously with the CDS spectra, were used to detect the coronal loop structure above the investigated network including its large-scale evolution and small-scale variability. Summarizing we can assume clear relation in energy transfer and/or mass motion between chromosphere and transition region but no relation was found between corona and the lower parts of the solar atmosphere above the particular network under study.

SUMER/SOHO and TRACE Study of the Transition Region Blinker

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Abstract

The most prominent transient event is presented from an extensive search for the transition region internetwork activity in the quiet solar atmosphere performed by SUMER/SOHO spectrometer and TRACE. SUMER spectra of Ly β line (1025.4 Å), two C II lines (1036.3 Å, 1037.0 Å) and O VI line (1037.61 Å) were used for determination of the spatial and temporal evolution of the transient event in the transition region. TRACE images taken in Ly α line (1216 Å), UV continuum (1700 Å) and Fe IX line (171 Å) were utilized in order to gain information about large-scale coronal structures and small-scale chromospheric variability in the vicinity of the transient event. The main physical and geometrical parameters of the event were derived for the transition region O VI line: the spatial extent of 11 000 km, duration for 9 minutes, intensity enhancement factor of 7 and the Doppler velocities of both signs up to 15km/s. According to these values the event was identified as a transition region **blinker**. The specific compensation of the solar rotation in steps for about 0.38" and the slit width (0.3") of the SUMER spectrometer with high temporal cadence (15 s) allowed to analyze the blinker with high resolution in spatial extent and time. Changes of the spectral parameters were caused by the slit displacements and the physical conditions in plasma. High deviations of the acquired O VI line profiles from singe-Gaussian and some multi-Gaussian profiles reveal dynamics of the event - occurence of the bi-directional jet which is not typical for blinkers. Besides rapid changes of the intensity and the velocity changes increase of width of O VI line were found up to 0.4, as well. Surrounding chromospheric and coronal structures around the event are discussed on base of the simultaneously taken TRACE images.

On relations of the calibrated parameters of the transition region spectral line

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Abstract

SUMER/SOHO measurements of the transition region emission line O VI line 1031.93 Å (280 000 K) in the network and internetwork are used for a statistical analysis of the calibrated spectral parameters: the central line intensity (energetic units), the line width (mÅ) and the Doppler shift (km/s). A detail procedure is performed in order to determine the correct zero point of the Doppler shift scale using the simultaneously observed chromospheric lines of O I. The spectral parameters of the O VI line are derived for both single and double Gaussian fitting of the line profiles according to the latest findings on the multi-component nature of the transition region line profiles. Effects of two classes of the transition region transient events – explosive events and blinkers – are discussed in relation to the overall dependences of the spectral parameters. Possible consequences of these statistical dependences for dynamics of the transition region are outlined.

Shock wave driven by a bubble travelling with high speed along an expanding loop

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Abstract

We report on a Coronal Mass Ejection (CME) observed on June 27 1999 by the UltraViolet Coronagraph Spectrometer (UVCS) telescope operating on board the SOHO spacecraft. The CME was also observed by the Large Angle Spectroscopic Coronagraph (LASCO). Emission of hot material has been recorded by UVCS propagating in front of an opening system of loops generated by the CME. The evolution of the UVCS structure is highly correlated to the evolution of the opening loop. The data reveal excess broadening of the O VI doublet lines and an enhancement in the intensity of the Si XII λ520.66 and λ499.37 lines due to the motion of the expanding hot gas. The hot gas emission seems to be due to a shock wave propagating in front of a very fast gas bubble travelling along the opening loop system.

Transient phenomena in a coronal hole and its borders registered by SUMER and EIT on-board SoHO

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Abstract

We present a study on an equatorial coronal hole registered by SUMER and EIT on-board SoHO. SUMER observations in Ne VIII and N IV have been analysed. The 10 hours continuous sit-and-stare mode observations permit a detailed analysis on transient phenomena in the coronal hole as well as on its borders. The simultaneous high-resolution EIT observations show the evolution of the coronal hole in great detail.

Radiance emission by flaring activity

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Abstract

Radiance values in the quiet Sun follow a lognormal distribution, with shape and scaling parameters varying significantly over the temperature range from chromosphere to corona. We show that these distributions can be reproduced by a simple model, which assumes that the radiance is produced by a stochastic (micro-, nano-) flaring process. This allows the diagnostic capabilities of the radiance distribution to be judged, performing, e.g., estimates of the true damping times of the flares. Several energy distributions are tested for the flaring process: constant, Gaussian and a power law. The resulting time series are compared with SUMER time series of equivalent sampling, after adjustment of the parameters of the simulation. A good statistical match of the measurements is obtained.

Transition region explosive events and their relation to the solar magnetic field

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Abstract

We present a preliminary analysis of a comparison of explosive events as observed in transition region (TR) spectral lines with SUMER with the spatial evolution of the corona as represented by EUV images of TRACE and the photospheric magnetic field as measured by MDI.

Coordinated SOHO and TRACE observations of solar polar jets

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Abstract

The solar polar jets are spectacular dynamic events originating in the flaring ultraviolet bright points within the polar coronal holes. They were originally observed by SOHO instruments (EIT, LASCO) during the last solar minimum in 1996 when the polar holes were the dominating coronal structures. UVCS/SOHO obtained ultraviolet spectroscopy of the jets providing us with the estimates for the jet plasma conditions, the evolution of the electron temperature and the heating rate required to reproduce the observed ionization state.

As the Sun is currently at the declining phase of its activity, the polar holes are again becoming permanent structures. The coordinated SOHO and TRACE observations were designed to identify and study the jet phenomena that would be the counterparts to the solar minimum polar jets.

We present the first results of the campaign. We discuss the dynamics of the recorded events and the preliminary results of the analysis of the jet plasma conditions. We also compare their properties with the polar jets observed during the last solar minimum.

Oscillations in coronal EUV bright points

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Abstract

The wavelet analysis of intensity variations of coronal EUV bright points, observed with SUMER and CDS (SoHO), in chromospheric, transition region and coronal lines has shown an oscillatory behaviour with periods of 400-600 sec. and 1000 sec. This intensity changes are correlated with electron density changes in the transition region. Preliminay results of JOP 166 (CDS-MDI-TRACE) to be run in July 2003 will also be presented.

Session 6: Wave acceleration in open magnetic regions

Invited Review: Theoretical aspects of wave acceleration in open magnetic structures

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Abstract

Theoretical studies of the solar wind outflow in open magnetic structures motivated by SOHO observations indicate that both, high frequency ion-cyclotron waves and low frequency MHD waves play a role in the acceleration and heating of the solar wind plasma. In particular, the high temperature anisotropy of O^{5+} ions deduced from SOHO UVCS observations suggests that resonant heating due to ion cyclotron waves is important in minor ions. However, there are theoretical difficulties with the ion-cyclotron wave heating model of protons. The low-frequency waves are required to transport energy and to accelerate the solar wind on large scales. In addition, the source of electron heating is still an open question. I will review some of the recent wave heating models of the fast solar wind that rely on low frequency (MHD) and high frequency (kinetic) waves. I will discuss the 3-fluid model, that describes electrons, protons, and minor ions as three coupled fluids. This description allows to model different properties and heating processes for each particle species and to model the high temperature of the minor ions in accordance with observations. I will review the results of 2.5D 3-fluid, simulations of the solar wind plasma that combine the effects of MHD waves self-consistently, and ion-cyclotron waves parametrically as the sources of energy. I will review the results of hybrid kinetic models of ion-cyclotron wave heating of the minor ions.

Invited Review: Observational Aspects of Wave Acceleration in Open Magnetic Regions

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Abstract

This presentation reviews the latest observational evidence for the existence of propagating waves in the open magnetic flux tubes of the solar corona. SOHO measurements have put tentative limits on the fluxes of various types of magnetohydrodynamic (MHD) waves in the acceleration region of the solar wind. Also, continually improving measurements of fluctuations at larger distances (i.e., in-situ detection and radio scintillation) continue to provide significant constraints on the dominant types of plasma oscillation throughout the corona and wind. The dissipation of MHD fluctuations of some kind, probably involving anisotropic turbulent cascade, is believed to dominate the heating of the extended corona. Spectroscopic observations from the UVCS instrument on SOHO have helped to narrow the field of possibilities for the precise modes, generation mechanisms, and damping channels. This presentation will also review some of the collisionless, kinetic aspects of wave heating and acceleration that are tied closely to the observational constraints.

Oral Contributions

A study of transition region and coronal Doppler shifts in a solar coronal hole

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Abstract

We present a study of a high spatial resolution raster scan taken on-disk with SUMER in a Polar Coronal Hole region. We have analysed the line shifts and widths of two EUV emitting ions, O III (703.87 Å) and Mg IX (706.02 Å). Our results constitute the lowest precise indication of fast wind streams seen originating from the network boundaries in the transition region.

Acceleration of the fast solar wind through minor ions

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Abstract

It is assumed that magnetic flux tubes are strongly concentrated at the boundaries of supergranule convection cells. A power law spectrum of high frequency Alfvén waves with a spectral index -1 originating from the sun is assumed to supply all the energy needed to energize the plasma flowing in such magnetic flux tubes. At the high frequency end, the waves are eroded by ions due to ion cyclotron resonance. The magnetic flux concentration is essential since it allows a sufficiently strong energy flux to be carried by high frequency ion cyclotron waves and these waves can be readily released at the coronal base by cyclotron resonance. The main results are: 1. The waves are capable of creating a steep transition region, a hot corona and a fast solar wind if both the wave frequency is high enough and the magnetic flux concentration is sufficiently strong in the boundaries of the supergranule convection zone. 2. By primarily heating alpha particles only, it is possible to produce a steep transition region, a hot corona and a fast solar wind. Coulomb coupling plays a key role in transferring the thermal energy of alpha particles to protons and electrons at the corona base. The electron thermal conduction then does the remaining job to create a sharp transition region. 3. Plasma species (even ions) may already partially lose thermal equilibrium in the transition region, and minor ions may already be faster than protons at the very base of the corona. 4. The model predicts high temperature alpha particles ($T_\alpha \sim 2 \times 10^7$K) and low proton temperatures ($T_p < 10^6$K) between 2 and 4 solar radii, suggesting that hydrogen Lyman lines observed by UVCS above coronal holes may be primarily broadened by Alfvén waves in this range.

Dynamics and properties of Coronal funnels

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Abstract

We present and discuss results of a 2D, Full MHD, time dependant, study of coronal funnels using a model that includes the high chromosphere, the transition region and the low corona. Plasma flow out of coronal funnels is investigated with a flux-tube model. The funnel-like configuration is defined by the magnetic field which is derived from an analytical 2-D magnetic field model(Hackenberg et al.,2000). The funnel is approximately 10 Mm high and 20 Mm wide. The plasma in the funnel is treated with one-fluid equations including the energy equation. We adjust the parameters to the quantities measured in the lower solar corona (100 000 km above the photosphere) by SUMER data onboard SOHO . We obtained 2D plasma properties (e.g. density, temperature, flow speed) within the funnel.

Ion heating across the magnetic field in the solar corona

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Abstract

The perpendicular heating of the ions observed by SOHO in the solar corona has been mainly attributed to the ion-cyclotron damping of high-frequency Alfvén waves. We investigate an alternative possibility that the dissipation range is formed by the Alfvén waves that are short-wavelength across the magnetic field - kinetic Alfvén waves (KAWs). The energy reservoir is provided by low-frequency large-scale MHD waves that are launched in the corona by the photospheric motions or excited at the coronal base by magnetic restructuring. The short perpendicular wavelengths can be developed by phase mixing, converting MHD Alfvén waves into KAWs, or KAWs can be excited in situ linearly or nonlinearly. Dissipative mechanisms become significant for KAWs with sufficiently short perpendicular wavelength. Here we focus on the dissipative effects due to finite KAWs amplitude. We show that above a threshold value of the amplitude KAWs can stochastically accelerate ions in the direction perpendicular to the background magnetic field. In particular, KAWs with transversal wavelengths of the order of the proton gyroradius and with a wave/background magnetic field ratio larger than 0.005, are accessible for the stochastic heating of oxygen ions. We discuss advantages of this mechanism over the ion-cyclotron heating scheme for the intense transverse heating of ions observed by SOHO at 2-4 solar radii.

Signatures of MHD waves in polar coronal hole regions

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Abstract

We examine long spectral time series of polar coronal holes observed with the Coronal Diagnostic Spectrometer (CDS) on-board SoHO. The observations were obtained in lines at transition region and coronal temperatures. In this work we report on the presence of long period oscillations, indicating the presence of waves with periods of 20 mins. or longer.

Posters

Observational constraints on ion acceleration by waves in coronal holes

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Abstract

The relationships between the deduced parameters of the coronal emission line of Mg X at 625 Å (with a formation temperature of about 1 MK) as observed by SUMER and the underlying magnetic field as measured by NSO/Kitt Peak have been investigated. It has been found that the line widths deduced from the Mg X line in different equatorial coronal holes show a clear trend to increase with the increasing underlying magnetic field strength (signed). Evidence for preferential heating and acceleration of heavy ions very near the Sun had previously been found in observations with UVCS and SUMER aboard SOHO. This suggests that dissipation of high-frequency Alfvén waves in coronal funnels may be a prime candidate for the heating of the magnetically open corona. Following this reasoning, our result seem to indicate that the wave-mechanical energy flux correlates with the strength of the magnetic field in coronal holes. Moreover, the spectroscopically obtainable quantity $v\sqrt{I}$ (with the intensity scaling like $I \sim n_e^2$), which is used here as a proxy for the coronal mass flux of the nascent fast solar wind, also reveals a clear positive correlation with the magnetic field strength. If this estimation of the mass flux (and its ratio between different holes) can be trusted, we could interpret our results as evidence that the mass flux is directly associated with the net magnetic flux density in a coronal hole.

A search for signatures of preferential heating by ion cyclotron waves in the low Corona

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Abstract

Pointing above the limb at the South Pole in May 2002 (MEDOC Campaign #9), with SUMER, we measure the width of more than twenty coronal ion lines. Assuming the same so-called "unresolved velocity" ξ for each ion, we derive the ion temperature, and plot it as a function of the ion charge-to-mass ratio. A heating of the minor ions in the corona, by way of ion cyclotron resonance, could result in a larger temperature for the ions presenting a lower charge-to-mass ratio (provided that their cooling time by the protons is not shorter than the heating time). Such signature is apparent in our data, if we set the unresolved velocity to a low value ($\leq$ 15 km.s^{-1}), but this effect may be primarily due to our data set : among the lines available in the SUMER spectral range, the lower charge-to-mass ratios are correlated with the larger masses, thus implying a larger influence of the value of ξ on the derived temperature. Setting a larger value for ξ, all ions tend to have the same temperature (within the error bars), except Fe X (with the lower charge-to-mass ratio), which still presents a larger temperature for ξ = 25 km.s^{-1}. Consequently, the uncertainty on the value of the unresolved velocity prevent from concluding hastily on the existence of a signature of preferential heating.

Session 7: Coronal Seismology

Invited Review: Theoretical aspects of MHD coronal seismology

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Abstract

MHD coronal seismology is a binary science based upon a delicate interplay of its observational and theoretical components. In the review, current trends in the development of the theoretical component are discussed. The topics covered are the modelling of global modes of coronal loops, in particular, processes responsible for their decay; theory of propagating fast and slow magnetoacoustic wave trains; and global coronal waves. The role of structuring, nonlinearity and non-ideal effects is discussed. The possibility of seismological determination of magnetic fields, transport coefficients, sub-resolution structuring and heat deposition positioning is demonstrated.

Invited Review: Coronal loop oscillations: Overview of recent results

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Abstract

Recent observations by high-resolution space imaging telescopes have revealed a variety of coronal oscillation modes. Now, in addition to radio observations of fast sausage mode oscillations, evidence exists for transverse kink-mode oscillations and propagating longitudinal waves in coronal loops detected by TRACE and SOHO/EIT. More recently, SOHO/SUMER discovered standing slow magnetoacoustic waves in hot coronal loops through Doppler shift measurements. We present overviews and comparisons of physical properties of different oscillation modes, and discuss their triggers and dissipation mechanisms. The application of coronal seismology models constrains the coronal magnetic field strength and dissipation efficiency, vital parameters for our understanding of coronal energy transport mechanisms.

Oral Contributions

Observations and theory of longitudinal waves in coronal loops

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Abstract

High cadence TRACE observations show that outward propagating intensity disturbances are a common feature in large, quiescent coronal loops, close to active regions. An overview is given of measured parameters of such longitudinal oscillations in coronal loops. The observed oscillations are interpreted as propagating slow magneto-acoustic waves and are unlikely to be flare-driven. A basic magnetic field extrapolation is used to estimate the local geometry of the magnetic field. A theoretical model of slow magneto-acoustic waves, incorporating the effects of gravitational stratification, the magnetic field geometry, thermal conduction and compressive viscosity is presented to explain the very short observed damping lengths. The results of these numerical simulations are compared with the TRACE observations. Preliminary results indicate that the magnetic field geometry plays an important role.

Coupled fast and Alfvén MHD waves in sheared coronal arcades

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Abstract

The magnetohydrodynamic (MHD) normal modes of oscillation of sheared coronal arcades including longitudinal wave propagation are studied. The wave equations for coupled fast and Alfvén modes in the cold plasma limit have been solved numerically using flux coordinates so that the curved magnetic structure is transformed into a straight field configuration. Our numerical code provides us with solutions in the form of the two-dimensional distribution of the perturbed velocity components together with the oscillatory frequency. Solutions have been computed in order to ascertain the effects of the longitudinal magnetic field component, B_y, and of the longitudinal propagation, k_y. Our results show that whenever $B_y \neq 0$ and/or $k_y \neq 0$ fast modes, characterized by a global velocity structure and a discrete spectrum of frequencies, and Alfvén continuum modes, characterized by a velocity perturbation confined to given magnetic surfaces, get coupled and no pure fast modes nor pure Alfvén modes exist, but modes with mixed properties arise. As a consequence, the spatial structure of the resulting oscillatory modes is characterized by a global spatial distribution together with a non-square integrable singular behavior on certain magnetic surfaces. Under certain circumstances, moreover, this mode coupling is such that the Alfvénic contribution is also in the form of a smooth velocity profile covering a range of magnetic surfaces instead of a singularity on a fixed magnetic surface. It turns out that the coupling between fast and Alfvén modes is governed by the parity of their eigenfunctions in the direction along the equilibrium magnetic field. The "parity rules" determining the features of coupled modes in terms of their parity, k_y and B_y are presented.

3D MHD simulations of the interaction of fast magnetosonic waves and coronal active regions

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Abstract

We present a three-dimensional MHD simulation of the local interaction between fast magnetoacoustic waves and coronal active regions. In order to have a realistic simulation, the active region magnetic field is calculated from the extrapolation of photospheric magnetograms. We include density profile for the 3D plasma flux tubes to simulate the loops in the active region. The corona is assumed to be isothermal and resistive dissipation is included in the model. We compare the main features of the simulated wave with a wave observed with the Transition Region and Coronal Explorer (TRACE). We find that many aspects of the simulation match the observations. In particular, we show how the wave's trajectory is modified, undergoing strong reflection and refraction away from the active region. We also show how the individual loops oscillate due to the interaction with the traveling wave. Finally, we discuss how we can use the simulations as a tool to understand the three-dimensional topology of active regions in anticipation of the STEREO mission. The stability of active regions and its relation with Coronal Mass Ejections is also analyzed.

Propagation of EIT Waves in Observations at Multiple Temperatures

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Abstract

EIT waves, so named because of their discovery in SOHO/EIT data, are a global wave phenomena, propagating in the corona. They appear to be intimately related to coronal mass ejections and also to classical Moreton waves. Models have demonstrated that the EIT wave is an MHD fast mode wave. Thus far, most studies of EIT waves have been limited to the EIT 195Åbandpass, corresponding to plasma at $T = 1.6$MK. Another limiting factor has been the cadence with which EIT images are taken. The SXI instrument on GOES-12 images the Sun over a broader range of temperatures, at a cadence at least as fast as EIT. We will investigate the propagation speed of EIT waves as a function of temperature (and thus altitude). In this paper we will present a selection of EIT waves observed with both SXI and EIT since January, 2003.

Short Period Fast Waves in Solar Coronal Loops

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Abstract

Short period fast magnetoacoustic waves propagating along solar coronal loops, perturbing the loop boundary along the line of sight (LOS), may be observed by imaging telescopes. The relationship between the difference in emission intensity, the angle between the LOS and the direction of propagation and the wave amplitude and wavelength, is explored for kink and sausage fast waves. It is shown that the compressibility of the plasma in the loop affects significantly the observability of the waves. For both wave types there is an optimal observation angle which is determined by the ratio of the wave length and the loop radius. The change of the observational conditions because of the loop curvature predicts a significant, up to an order of magnitude, change in the observed wave amplitude. This prediction is confirmed by the analysis of the evolution of the fast wave train amplitude, observed with the SECIS instrument. The wave train amplitude experiences a sharp increase and then a decrease along the loop. The observational results are in a good agreement with the theory.

Damping of coronal EIT waves as a tool for plasma diagnostics

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Abstract

Observations with the Extreme-Ultraviolet Imaging Telescope (EIT) on-board SOHO have revealed the existence of transient coronal waves generated by an impulsive event (e.g. flare) that propagate across the visible solar disk over very long distances. The present work aims to discuss one the most remarkable properties of waves, namely, how to obtain information about the medium these waves pass through. Extracting such information from observations (i.e. propagation speed, attenuation length, dissipation coefficients) we use these waves for plasma diagnostics, i.e. for *global coronal seismology*. Applying a simple coronal model, we find average values of magnetic field at the propagation height of the EIT waves, as well as average values for the viscosity coefficient. Multi-wavelength analysis of EIT waves is carried out in order to establish the correspondence of these wave at different temperatures.

Damping of loop oscillations in the stratified corona

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Abstract

SOHO and TRACE observations have confirmed the theoretical predictions by Roberts et al. (1984) almost two solar cycles ago, namely, coronal loops may oscillate. These oscillations, and in particular their damping, are of fundamental importance for solar physics since they can provide diagnostics of the plasma medium. In the present paper we apply this concept to hot and *stratified* and non-isothermal coronal loops observed by e.g. TRACE or SUMER on-board SOHO. We investigate the effect of stratification on (i) the damping of standing waves and (ii) on propagating coherent disturbances (i.e. basically slow MHD waves). The effect of stratification results, if we may say so, in an approximate 15-20% of reduction in damping time for the parameter regime that characterise hot SUMER or TRACE loops. This is a good news as theoretical speculations in the literature usually suffer from an over-estimate of the damping of oscillations caused by e.g. thermal conduction or viscosity in the non-stratified atmosphere approach.

Hydrodynamic Simulations of Longitudinal Intensity Oscillations Observed in Coronal Loops by TRACE

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Abstract

Propagating intensity disturbances are often observed by TRACE in large coronal loops located at the perimeters of active regions (e.g., De Moortel et al., 2002, Solar Phys., 209, 61). On average, the disturbances have periods of 280 s, propagation speeds of 120 km s^{-1}, intensity amplitudes of 4%, and surprisingly small damping (detection) lengths of 9000 km. In addition, there is a positive correlation between damping length and period. The preliminary interpretation of these disturbances is that they are rapidly dissipating slow magneto-acoustic waves.

To investigate this interpretation more rigorously, we have performed a series of detailed coronal loop simulations using our 1D hydrodynamic code, ARGOS. We generate waves in the loop by imposing a spatially localized oscillating force at the loop footpoints. We here report on the results of our study and, in particular, whether the damping lengths have the properties observed by TRACE.

This work was supported by NASA and ONR.

Damping of coronal loop oscillations

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Abstract

The analytic study of coronal loop oscillations in equilibrium states with thin n onuniform boundary layers is extended by a numerical investigation for fully nonunifor m 1D equilibrium states. The frequency and the damping time of the ideal kink quasi -mode are calculated in fully resistive MHD. In this numerical investigation there i s no need to adopt the assumption of a thin nonuniform boundary layer which is essentia l for analytic theory. The dependence of the complex frequency of the kink mode on the width of the boundary layer, the length of the loop and the density contrast between the internal and the external region is studied and is compared with analytical theory. When the boundary layer width is varied, differences between the analytically obtained damping rates and the numerical results become as large as 25%.

Preliminary results from SECIS observations of the 2001

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Abstract

The Solar Eclipse Coronal Imaging System (SECIS) has been modified and used to observe the 2001 total Solar Eclipse from Zambia. A higher signal-to-noise ratio was achieved as a much broader green filter was used and a new alignment method was applied to the 8000 images taken during observations. Those changes led to better quality data and the authors would like to present some preliminary results that confirm previous detections of oscillations by SECIS during the 1999 total Solar Eclipse.

Posters

Sunward flows and coronal oscillations: analysis of 21 April 2002 observations of supra-arcade downflows

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Abstract

An X1.5 limb flare on 21 April 2002 developed a large supra-arcade in which TRACE EUV images show dark structures falling toward the Sun with velocities up to 200 km s^{-1} from heights about 150 Mm above the solar limb. The falling structures trigger kink mode oscillations with periods of $\sim$ 5 min in the surrounding plasma. Simultaneous SUMER spectra of Doppler shift and intensity variations in the arcade loops and infalling structures give (i) precise constraints on the temperature and density of the infalling plasma, (ii) show 1000 km s^{-1} Fe XXI line shifts from 10^7 K plasma, and (iii) Fe XXI Doppler shifts oscillations associated with the TRACE intensity oscillations.

Intensity Oscillations of the Coronal X-ray Bright Points

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Abstract

The relation of X-ray Bright Points (XBPs) with the underlying photospheric and chromospheric features is an important issue in understanding the origin of the footpoints of XBPs and hence to study the heating of the quiet corona. We have used a long time sequence of the full-disk soft X-ray images obtained at both low and high temporal resolution with soft X-ray telescope (SXT) of *Yohkoh* mission to bring out the differences, if any, in the period of intensity oscillations associated with XBPs. We derived the energy flux of the XBPs for the entire sequence and for the XBPs of 10-days observations selected during 1992, 1993 and 1994. The light curves of the XBPs have been produced. We classified the XBPs into three groups depending on their emission levels: (i) the quiet XBPs; (ii) less bright XBPs; and (iii) the very bright XBPs. The power spectrum analysis has been done using their energy flux values to determine the period of intensity oscillations. A significant periodic intensity variations with Fourier transform power peaks have been detected around 8 ± 0.61 hours and 1 ± 0.25 hour in the case of low temporal resolution of longer duration (more than 24 hours) of observations, although there are secondary peaks with smaller amplitude in power. We conclude that the XBPs are mainly associated with two kinds of period of oscillations in their intensity variations, namely the 8 ± 0.61 hours and 1 ± 0.25 hour. In comparison among these three regions with different X-ray emission levels, we have found that the period of intensity oscillations is similar in all the cases. This can be taken as evidence to argue that heating mechanism in all the three groups of XBPs is similar. This confirms the similar argument drawn for the three classes of chromospheric CaII K bright points (Kariyappa, 1996, 1999 and 2002). The analysis of high temporal resolution with a shorter duration (about 2 hours and 30 minutes) of observations of XBPs show that they exhibit a shorter periodicity of 6-7 min in their intensity variations, although this is not seen in the longer duration of observations due to the low temporal resolution.

Inductive interaction of coronal currents as a possible source for magnetic loops oscillations in solar active regions

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Abstract

Inductive interaction of longitudinal currents in groups of slowly growing magnetic loops is considered. Each loop is modelled by an equivalent electric circuit with variable resistance and inductive coefficients. These parameters of the electric circuit are defined by geometry and position of the loop with respect to neighbouring loops, as well as on the plasma temperature and density in the magnetic tube. Ponderomotoric interaction of the electric circuits of the current-carrying magnetic loops is studied. Possible dynamics and conditions for stability of the interacting magnetic loops are considered. Special attention is paid to the possibility of oscillations or fast change of an inclination of the loops, which could result in their coalescence and reconnection. The main characteristics of the oscillatory dynamics of a loop were calculated and compared with the observed ones.

Slow nonlinear waves in solar corona: exact analytical theory

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Abstract

It is shown, that the current theory of slow waves suffers from shortcomings and confusions. All considerations of weakly nonlinear waves in solar corona are based on wrong or very crude approximations of the dispersion of slow waves. The theory of weakly nonlinear waves based on the exact dispersion relation is developed. New nonlinear equation and its exact analytical solution is presented. The conditions of the appearance of slow shocks in the corona are discussed. The observations of slow waves in solar corona are discussed.

Hot coronal loop oscillations observed with SUMER: Advanced modeling

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Abstract

We perform advanced numerical modeling of hot coronal loop oscillations observed with SUMER using 1D loop hydrodynamic model, that incorporates the effects of gravitational stratification, heat conduction, radiative losses, added external heat input, presence of Helium, and Braginskii viscosity. The model also takes into account presence of the the transition region and dense chromosphere. Previously, these oscillations have been identified as standing slow magnetosonic waves. A number of issues such as the wave excitation mechanisms and observed propagating Doppler shifts, which were not explained by other recent models, are addressed.

Coronal Seismology by MHD Autowaves

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Abstract

Slow magnetoacoustic waves are routinely observed in solar coronal structures. These waves can be strongly affected by non-adiabatic effects leading to self-organising compressible propagating disturbances - magnetoacoustic autowaves. These are waves which have parameters independent of the excitation that are determined by the parameters of the medium only and, consequently, are potentially an ideal tool for coronal seismology. The influence of non-adiabatic effects is studied and magnetoacoustic autowaves are modelled with the extended Burgers equation. A numerical code is developed to study the evolution of such waves and a parametric study is carried out. Observable parameters of coronal magnetoacoustic autowaves could provide a tool for the determination of heat deposition mechanisms in the corona.

Fast Magnetohydrodynamic oscillations in coronal loops with heating profiles

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Abstract

Loop oscillations have been abundantly reported during the last few years. Using an isobaric and thermal equilibrium with different heating functions, a density profile for a loop is derived, and then its oscillatory modes are studied. The main result is that the frequency and spatial structure of the trapped modes are very sensitive to variations of density inside the loop, specially in the appex, which depends strongly on the footpoint density and the ratio of heating to thermal conduction. Moreover, different tested heating profiles give more or less the same results that for the case of constant heating all along the loop.

Non adiabatic MHD waves in the Solar Corona

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Abstract

Nowadays, the presence of oscillations in solar coronal structures is well known from ground-based and space observations. To explain these reported oscillations, many theoreticals models based on linear and adiabatic MHD waves have been set-up. However, although it can provide with a further explanation for the damping of oscillations, the non-adiabatic regime has been poorly explored. In this paper, we study the time damping of magnetoacoustic waves when the adiabaticity assumption has been removed by means of an energy equation which includes radiative losses (optically thin), thermal conduction and heating. For sake of simplicity, this study has been done for a homogeneous, isothermal and unbounded medium permeated by a horizontal and uniform magnetic field, then, by modifying the physical parameters of the medium, temperature and density, several different regimes can be studied. Here, we have paid special attention to the cases akin to coronal, prominence-corona transition region (PCTR) and prominence conditions, and for these regimes, we have gathered information about the period, damping time and damping per period of linear nonadiabatic magnetoacoustic waves.

3D numerical simulations of impulsively generated MHD waves in solar coronal loops

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Abstract

Impulsively generated magnetohydrodynamic waves in solar coronal loops are studied by numerical means with a use of the three-dimensional FLASH code. Our results reveal that all kinds of MHD modes excited exhibit distinctive time signatures which are collected at a detection point inside a loop. An interaction between MHD waves as well as various wave excitation mechanisms lead to complex time signatures which are strongly influenced by wave excitation mechanism and contain seismological information about the loop cross-section structure. We discuss also the observational detectability of such MHD waves in optical, radio, and soft X-ray wavelenghts.

SUMER observations of heating and cooling of active region loops

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Abstract

High-velocity events observed by SUMER in hot EUV lines are known to trigger loop oscillations. Apart from the inference of physical parameters in the solar corona, these observations also carry the signatures of heating and cooling of coronal loops. We present the light curves for various highly-ionized ions which were simultaneously observed during and after the trigger. Even though the majority of SUMER events occurs on subflare level, it is clear that the heating is impulsive and drives the plasma to a very high temperature of up to 10 MK within minutes. During the cooling phase, however, we find the plasma in gradually decreasing ionization stages which implies that the entire loop system involved in such events is basically in the isothermal state. Such events may also help in our understanding of mass supply and energy transport in the corona.

Time-Frequency analysis of quasi-periodic signals

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Abstract

In recent years, the analysis of quasi-periodic signals observed by satellites such as SOHO and TRACE has become increasingly important. So far, mostly standard methods have been used, such as Fourier analysis to identify the dominant frequencies and wavelet analysis, which has the advantage of providing the time localisation of the various frequency components. We compare the temporal and frequency resolution of different 'time-frequency' methods. In particular, the usefulness and robustness of wavelet analysis is investigated by varying the different parameters which characterise the 'mother' wavelet. Both simple harmonic functions and intensity oscillations observed by TRACE are used to demonstrate the various advantages and disadvantages of the different methods.

Application of EMD and CEOF techniques to the analysis of coronal oscillations

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Abstract

In this work, we investigate the application of two different techniques to temporal coronal signals. The first technique is used to decompose a signal in its characteristic time scales, and the second one is designed to identify the dominant spatial and temporal structures in a multivariate data set in order to analyze propagating features that can be associated with waves. The Empirical Mode Decomposition (EMD) method was developed by Huang et al. (1998) and can be used to decompose a signal in its intrinsic time scales allowing, among others, to filter the signal efficiently. On the other hand, the Complex Empirical Orthogonal Function (CEOF) analysis is an extension of the usual Principal Component analysis in which the Hilbert transform has been added, allowing for an effective detection of propagating features. Some results of the application of both methods to different solar coronal structures are presented here.

Observational Tests of Damping by Resonant Absorption in Coronal Loop Oscillations

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Abstract

One of the proposed damping mechanisms of coronal (transverse) loop oscillations in the kink-mode is resonant absorption as a result of the Alfvén speed variation at the outer boundary of coronal loops. Analytical expressions for the period and damping time exist for loop models with thin non-uniform boundaries. They predict a linear dependency of the ratio of the damping time to the period on the thickness of the non-uniform boundary layer. Ruderman and Roberts used a sinusoidal variation of the density in the non-uniform boundary layer and obtained the corresponding analytical expression for the damping time. Here we measure the thickness of the non-uniform layer in oscillating loops for 11 events, by forward-fitting of the cross-sectional density profile $n_e(r)$ and line-of-sight integration to the cross-sectional fluxes $F(r)$ observed with TRACE 171 Å. This way we model the internal n_i and external electron density n_e of the coronal plasma in oscillating loops. This allows us to test the theoretically predicted damping rates for thin boundaries as function of the density ratio $\chi = n_e/n_i$. Since the observations show that the loops are fully non-uniform we also use numerical results for damping rates to determine the value of χ for the loops. We find that the density ratio predicted by the damping time, $\chi_{LEDA} = 0.53 \pm 0.12$, is about a factor of 3.0 ± 2.1 higher than the density ratio estimated from the background fluxes, $\chi = 0.23 \pm 0.11$. The lower densities modeled from the background fluxes are likely to be a consequence of the neglected hotter plasma that is not detected with the TRACE 171 Å filter, as well as due to the neglect of the FIP-effect for relative iron enhancement in the oscillating loops. Taking these corrections into account, resonant absorption is consistent with the observed damping times of kink-mode oscillations and provides a new density diagnostic in the environment of oscillating loops.

Oscillations of coronal loops with elliptic cross-sections

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Abstract

Motivated by the Transition Region and Coronal Explorer (TRACE) observations of damped oscillations in coronal loops, Ruderman & Roberts [2002, ApJ, 577, 475] studied resonant damping of kink oscillations of thin straight magnetic tubes in a cold plasma. We extend their analysis for magnetic tubes with elliptic cross-sections. We found that there are two kink modes: one polarized along the small and the other polarized along the large axis of the elliptic cross-section. For moderate values of the ratio of the axis of the elliptic cross-section the damping time of the two kink modes due to resonant absorption does not differ very much from the damping time of kink modes in tubes with circular cross-section.

Diagnosing MHD wave detections in the solar corona

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Abstract

Filtergram experiments, such as *SoHO*'s *EIT* and the Phillips et al. (2000) *Solar Eclipse Corona Imaging System* have successfully detected MHD modes in coronal structures. However, all such experiments have suffered to varying degrees from the lack of (line-of-sight) velocity information. Trapped modes – torsional Alfvén waves, fast and slow kink and sausage waves – will all ideally manifest different velocity and density perturbation profiles, but current instrumentation cannot meet the spatial, spectral and temporal resolutions required to differentiate between these modes at high frequencies. We present various possibilities for the diagnosis of such waves with existing instruments, and the possibilities for detections with the next generation of instruments such as *Solar-B*'s *EIS* and the *MOSES* rocket spectrograph design.

Propagating oscillations within active region loops – Joint observations with SOHO/CDS and TRACE

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Abstract

Observations of propagating intensity oscillations have been observed extensively at coronal temperatures with TRACE in the 171Å passband. A TRACE 171 propagation within a coronal loop is analysed along with co-spatial, co-temporal observations of CDS. Results are presented of coincident periodicity at the same location and time at chromospheric, transition region and coronal temperatures. Possible explanations for this feature are discussed as well as future observing programmes for further detection of such quasi-periodic variability at the base of loops.

Observations of temporal variations in the O VI line : loop oscillations in relatively cool plasma ?

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Abstract

We report off-limb observations of the O VI line at 1031.9 Å, with high temporal cadence (30 s), using SUMER pointing 33 arcsec above the solar limb, on the West Equator. During one hour of observation, this line presented four bursts in intensity (the larger one not exceeding an intensity increase of 80 %), each one accompanied by strongly damped Doppler shift oscillations (with a period of about 7 minutes). This observations are similar to those of Wang et al. 2002 (ApJ. 574, L101, with SUMER), although our curves are more noisy, mostly because the amplitudes of variation are far less large. To our knowledge, these authors always observed such kind of oscillations in very hot lines, whereas the temperature range of O VI doesn't exceed 2 MK, which is more comparable with the temperature range where loop oscillations have been reported using TRACE data.

Closing Summary Review

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Abstract

In the Closing Summary Review we attempt to synthesize the contributions of this workshop, will emphasise what we have learned during the meeting, what key developments we are still missing, and what could be the key future issues in the theme of the conference.